CLAIMS

What is claimed is:

1. An apparatus which integrates power and bi-directional data transmission in order to control the operation of and monitor information from various electrical equipment modules in a control system comprising:

a. two conductors of alternating current electrical power including
   a first conductor acting as a voltage supply line; and
   a second conductor, the second conductor capable of being at once
      a return conductor for power distribution; and
      a return conductor for asynchronous data transmission;

b. at least one controller electrically connected to said two conductors for the generation and transmission of a data signal; and

c. at least one addressable controlled device having a device address associated therewith, the controlled device being electrically connected to said two conductors and capable of receiving said data signal generated by said controller;

wherein said data signal is comprised of bursts of sinusoidal waves superimposed onto said alternating current electrical power transmitted on said two conductors, said sinusoidal waves being of uniform frequency, said uniform frequency being a higher frequency than the frequency of said alternating current electrical power, said superimposition occurring within a single half-cycle of selected polarity of said alternating current electrical power.

2. The apparatus of Claim 1 wherein a first type of said bursts of sinusoidal waves is a synchronization pattern.

3. The apparatus of Claim 1 wherein a second type of said bursts of sinusoidal waves represents data bits.

4. The apparatus of Claim 1 wherein said alternating current electrical power is of a known frequency and has zero crossings.

5. The apparatus of Claim 4 wherein said superimposition of bursts of sinusoidal waves is referenced to one of said zero crossings of said alternating current electrical power as a first reference.

6. The apparatus of Claim 5 wherein said bursts of sinusoidal waves include a first burst, said first burst is of a first type of said bursts of sinusoidal waves, said first type is a synchronization pattern, said synchronization pattern contains a second reference following said first reference, said second reference is a phase reversal of said sinusoidal waves.

7. The apparatus of Claim 6 wherein said bursts of sinusoidal waves may optionally include one or more subsequent bursts of a second type, said second type of said bursts represents a data bit.

8. The apparatus of Claim 7 wherein a first of two possible binary states of said data bit is indicated by the presence of a minimum number of cycles of said sinusoidal waves within a time slot, and a second of the two possible binary states of said data bit is indicated by the absence of said minimum number of cycles of said sinusoidal waves within said time slot, said time slot is referenced to, and offset in time from, said second reference.

9. The apparatus of Claim 8 wherein a set of consecutive data bits forms a data byte, said data byte is coded in a set of consecutive time slots, each time slot of said set of consecutive time slots sequentially represents a next one of said set of consecutive data bits.

10. The apparatus of Claim 9 wherein no more than one of said data byte is coded within an instance of said single half-cycle of selected polarity of said alternating current electrical power.

11. The apparatus of Claim 9 wherein said data signal includes a multiplicity of communications sequences, each communications sequence comprises exactly one of said synchronization pattern followed by a set of coded data bytes.

12. The apparatus of Claim 11 wherein said set of coded data bytes within said communications sequence comprises:

a. a first byte, said first byte follows said synchronization pattern and is precisely delayed a first amount of time from said second reference and occurs within a first of a set of said single half-cycle of selected polarity of said alternating current electrical power, said first byte is an address;
b. a second byte, said second byte is precisely delayed a second amount of time from said second reference and occurs within a second of a set of said single half-cycles, said second byte is a command;
c. third and fourth bytes, said third and fourth bytes are precisely delayed a third and fourth amount of time from said second reference and occur within third and fourth of a set of said single half-cycles, said third and fourth bytes are data associated with said command;
d. fifth and sixth bytes, said fifth and sixth bytes are precisely delayed a fifth and sixth amount of time from said second reference and occur within fifth and sixth of a set of said single half-cycles, said fifth and sixth bytes are response to said command;
e. a seventh byte, said seventh byte is precisely delayed a seventh amount of time from said second reference and occurs within a seventh of a set of said single half-cycles, said seventh byte is status; and

f. an eighth byte, said eighth byte is precisely delayed an eighth amount of time from said second reference and occurs within an eighth of a set of said single half-cycles, said eighth byte is a checksum over all of said first through seventh bytes.

13. The apparatus of Claim 12 wherein said synchronization pattern and said first through fourth bytes are generated and transmitted by a first of said at least one controller and said fifth through eighth bytes are generated and transmitted by a selected device of said at least one addressable controlled device, said selected device having been selected by a match of address transmitted in said first byte of said set of coded data bytes within said communications sequence.

14. A communications network comprised of the apparatus of Claim 12 wherein said synchronization pattern and said first through fourth bytes are generated and transmitted by a first of said at least one controller, and said first byte, being said address, contains the zero code, and all of said controlled devices on said communications network respond to said command and to said data associated with said command transmitted in said second through fourth bytes, but none of said controlled devices transmits any response during the time slots designated for said fifth through eighth bytes of said communications sequence.

15. The communications network of Claim 14 wherein at least 255 instances of said at least one addressable controlled device may be independently controlled by unique addresses transmitted in said first byte of said communications sequence.

16. The apparatus of Claim 1 wherein said alternating current electrical power has a voltage in the range of 10 VAC to 30 VAC.

17. The apparatus of Claim 1 wherein said alternating current electrical power has a voltage that is nominally 24 VAC.

18. The apparatus of Claim 1 wherein said alternating current electrical power has a voltage in the range of 100 VAC to 130 VAC.

19. The apparatus of Claim 1 wherein said alternating current electrical power has a voltage in the range of 200 VAC to 240 VAC.

20. The apparatus of Claim 1 wherein said alternating current electrical power has a frequency that is nominally 50 Hz.

21. The apparatus of Claim 1 wherein said alternating current electrical power has a frequency that is nominally 60 Hz.

22. The apparatus of Claim 1 wherein said sinusoidal waves have a frequency that is in the range of 1 kHz to 50 kHz.

23. The apparatus of Claim 1 wherein said sinusoidal waves have a frequency that is nominally 19.2 kHz.

24. The apparatus of Claim 1 wherein said electrical equipment modules include solenoid valves for an irrigation system.

25. The apparatus of Claim 1 wherein said electrical equipment modules include instrumentation for a deep earth well.

26. The apparatus of Claim 1 wherein said electrical equipment modules include sensors of soil, water or weather conditions, said sensors being capable of sensing one or more of soil moisture, soil temperature, soil

conductivity, soil acidity, soil permeability, water flow, water pressure, air temperature, wind speed, humidity, and incident solar radiation.

27. The apparatus of Claim 1 wherein said electrical equipment modules include sensors for use in a security system, said sensors being capable of sensing one or more of motion, temperature, and the presence or depth of surface water.

28. The apparatus of Claim 1 wherein said electrical equipment modules include controls for outdoor lighting.

29. The apparatus of Claim 1 wherein said electrical equipment modules include controls for gates or other means of controlling access to an area.

30. A method of transmitting data by a controller on a two-wire network carrying alternating current electrical power, said method comprising within said controller device the steps of:

a. detecting a zero-crossing of said alternating current electrical power;
b. delaying a first delay time after said zero-crossing;
c. superimposing a modulation frequency onto said alternating current electrical power;
d. introducing a 180-degree phase shift into said modulation frequency after a particular quantity of cycles of said modulation frequency, said phase shift to be used as a timing reference, and continuing said modulation frequency for a total quantity of synchronization cycles of said modulation frequency; and
e. transmitting a set of data bytes by further superimposition of said modulation frequency onto said alternating current electrical power, each bit of each byte of said set of data bytes being assigned to a corresponding bit-wise time slot from a set of bit-wise time slots, each said bit-wise time slot being referenced in time from said timing reference, each '1' bit being encoded by the presence of a data quantity of cycles of said modulation frequency

during said corresponding bit-wise time slot, and each '0' bit being encoded as the absence of said data quantity of cycles of said modulation frequency during said corresponding bit-wise time slot.

31. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein:

a. said bit-wise time slots are clustered into a set of byte-wise time slots with no delays between said bit-wise time slots within each of said byte-wise time slots;

b. each of said byte-wise time slots is separated in time from adjacent byte-wise time slots so that no more than one of said byte-wise time slots occurs within any half-cycle of said alternating current electrical power; and

c. said byte-wise time slots are restricted to occur during allowed half-cycles of said alternating current electrical power where said allowed half-cycles have a given polarity of said alternating current electrical power and alternate half-cycles, having polarity opposite of said given polarity, are disallowed.

32. The method of Claim 31 for transmitting data by a controller on a two-wire network, wherein said set of data bytes are transmitted in said set of byte-wise time slots, and said set of byte-wise time slots comprises:

a. a first byte-wise time slot, a first data byte of said set of data bytes is transmitted by a controller in said first byte-wise time slot, said first byte-wise time slot follows said total quantity of synchronization cycles, both of said total quantity of synchronization cycles and said first byte-wise time slot occur in a first of said allowed half-cycles, said first byte is an address;

b. a second byte-wise time slot, a second data byte is transmitted by said controller in said second byte-wise time slot, said second byte-wise time slot occurs within the next allowed half-cycle following said first byte-wise time slot, said second data byte is a command;

c. third and fourth byte-wise time slots, said third and fourth data bytes are transmitted by said controller in third and fourth byte-wise time slots, said

third and fourth byte-wise time slots occur within the next two allowed half-cycles following said second byte-wise time slot, said third and fourth data bytes are data associated with said command; and

d. four reserved byte-wise time slots, said reserved byte-wise time slots allow said controller to receive data bytes transmitted by a selected controlled device.

33. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said modulation frequency is in the range of 1 kHz to 50 kHz.

34. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said modulation frequency is nominally 19.2 kHz.

35. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 10 VAC to 30 VAC.

36. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a voltage that is nominally 24 VAC.

37. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 100 VAC to 130 VAC.

38. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 200 VAC to 240 VAC.

39. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a frequency that is nominally 50 Hz.

40. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said alternating current electrical power has a frequency that is nominally 60 Hz.

41. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said controller controls an irrigation system.

42. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said controller controls one or more sensors of soil, water or weather conditions, said sensors being capable of sensing one or more of soil moisture, soil temperature, soil conductivity, soil acidity, soil permeability, water flow, water pressure, air temperature, wind speed, humidity, and incident solar radiation.

43. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said controller controls a security system.

44. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said controller controls a lighting system.

45. The method of Claim 30 for transmitting data by a controller on a two-wire network, wherein said controller controls instrumentation in a deep earth well.

46. A method of receiving data by an addressable controlled device on a two-wire network carrying alternating current electrical power, said method being implemented within said addressable controlled device and comprising the steps of:

a. finding a zero-crossing of said alternating current electrical power;
b. delaying a first delay time after said zero-crossing;
c. searching for a signal frequency within a desired frequency band on said alternating current electrical power while measuring a first elapsed time, and returning to said detecting step if said first elapsed time reaches a first maximum elapsed time before said signal frequency is recognized;
d. detecting a phase reversal of said signal frequency while counting cycles of said signal frequency, and returning to said finding step if said counting reaches a first maximum count;
e. operating a virtual clock generator at said signal frequency, said virtual clock generator is synchronized to said phase reversal and starts a received data timer upon said detecting of said phase reversal;
f. establishing a set of time windows based upon said received data timer wherein each received data bit belonging to a set of received data bits is expected to fall within a corresponding time window within said set of time windows;
g. counting cycles of said signal frequency within each of said time windows; and
h. assigning a logical data bit value of '1' to said received data bits where said step of counting cycles yields at least a required minimum data count of cycles during said corresponding time window, and assigning a logical data bit value of '0' to said received data bits where said step of counting cycles fails to reach said required minimum data count of cycles during said corresponding time window.

47. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein a set of received data bytes is constructed by grouping of said received data bits into said set of received data bytes.

48. The method of Claim 47 for receiving data by an addressable controlled device on a two-wire network, wherein said set of time windows established by said step of establishing a set of time windows includes a sufficient quantity of said time windows to accommodate construction of at least eight of said received data bytes.

49. The method of Claim 48 for receiving data by an addressable controlled device on a two-wire network, wherein said method further comprises the steps of:

a. comparing a first received data byte of said set of received data bytes to a pre-assigned address of said addressable controlled device, said first received data byte is taken as an address byte;
b. ignoring said set of received data bytes if said comparing step is not a match and said first received data byte is not zero;
c. taking a first action by said addressable controlled device in accord with a first pre-programmed function when said first received data byte is zero, said first action may optionally depend upon a second received data byte, a third received data byte and a fourth received data byte, said first action will not cause any data to be transmitted by said addressable controlled device;
d. taking a second action by said addressable controlled device when said first received data byte matches said pre-assigned address of said addressable controlled device as tested in said comparing step, said second action being selected from a set of pre-programmed functions determined by a second received data byte, said second received data byte taken as a command, optionally using a third received data byte and a fourth received data byte to modify said second action;
e. transmitting onto said two-wire network a fifth data byte and a sixth data byte, said fifth data byte and said sixth data byte being composed in accordance with said second action, and said fifth data byte and said sixth data byte being transmitted during those time windows within said set of

time windows that correspond to a fifth data byte and a sixth data byte of said at least eight of said received data bytes;

f. reporting onto said two-wire network a seventh data byte, said seventh data byte being composed to report status of said addressable controlled device following said second action, and said seventh data byte being reported during that time window within said set of time windows that corresponds to a seventh data byte of said at least eight of said received data bytes;

g. confirming onto said two-wire network an eighth data byte, said eighth data byte being composed as a checksum of said first through seventh data bytes, and said eighth data byte being confirmed onto said two-wire network during that time window within said set of time windows that corresponds to an eighth data byte of said at least eight of said received data bytes; and

h. said steps of transmitting, reporting and confirming being accomplished by superimposing onto said two-wire network a quantity of full cycles of said signal frequency to fill each of said time windows where a '1' bit is to be encoded, and inhibiting modulation during those of said time windows in which a '0' bit is to be encoded.

50. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said signal frequency is in the range of 1 kHz to 50 kHz.

51. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said signal frequency is nominally 19.2 kHz.

52. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 10 VAC to 30 VAC.

53. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a voltage that is nominally 24 VAC.

54. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 100 VAC to 130 VAC.

55. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a voltage in the range of 200 VAC to 240 VAC.

56. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a frequency that is nominally 50 Hz.

57. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said alternating current electrical power has a frequency that is nominally 60 Hz.

58. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device is a solenoid valve in an irrigation system.

59. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device is a sensor of soil, water or weather conditions, said sensor being capable of sensing one or more of soil moisture, soil temperature, soil conductivity, soil acidity, soil permeability, water flow, water pressure, air temperature, wind speed, humidity, and incident solar radiation.

60. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device is a sensor for use in a security system, said sensor being capable of sensing one or more of motion, temperature, and the presence or depth of surface water.

61. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device is a lamp control.

62. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device controls a gate or other means of restricting access to an area.

63. The method of Claim 46 for receiving data by an addressable controlled device on a two-wire network, wherein said addressable controlled device is instrumentation in a deep earth well.